System Specification

For

Large Force Shaker System for the White Sands Missile Range (WSMR)

U.S. Army Program Executive Office for

Simulation, Training and Instrumentation

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Revision Number	Date	Log of Changes Made and Description of Reason Changes	Approved By
1.0	2 May 17	Initial Draft	
2.0	31 May 17	Final Draft	
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3.1	6 July 17	Second Revised Final Draft to correct errors in paragraphs 3.1.1.5, 3.1.1.6, 3.2.3, 3.2.7.9. 3.2.9.4.e, and 4.2. Revised both Figures and deleted paragraph 3.2.9.4.c.	
3.2	25 July 17	deleted first sentence in paragraph 3.2.3. and added "rack mountable" to paragraph 3.2.12 second sentence.	
3.3	26 July 17	deleted first occurrence of “air” in first sentence of Paragraph 3.2.3	

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Performance Specification

For

Large Force Shaker System for the White Sands Missile Range (WSMR)

1. SYSTEM SPECIFICATION.

This System Specification provides the minimum performance requirements for a new large force electrodynamic vibration test system. The system will be installed in Building 19476 (Bay 6, 300k Test Facility) and configured for conducting shock and vibration testing of Army materiel at WSMR.

1.1 Background.

The U.S. Army Program Executive Office for Simulation, Training and Instrumentation, Project Manager for Instrumentation, Targets and Threat Simulators and SOF Training Systems, Instrumentation Management Office (PM ITTS, IMO) provides test instrumentation to the test and evaluation community, and is the materiel developer for the Large Force Shaker System Modernization at WSMR.

2. APPLICABLE DOCUMENTS.

MIL-STD-810G CN1, Method 514.7 (Vibration) and Method 516.7 (Shock).

3. REQUIREMENTS

3.1 System Performance Requirements.

The Large Force Shaker System shall perform tests in accordance with MIL-STD-810G CN1, Method 514.7 (Vibration) and Method 5.16.7 (Shock). The system shall provide 3-inch peak to peak displacement and shall be rated at least 55,000 lbs force root mean squared (rms) continuous random vibration duty. The new system shall include a 5-foot by 5-foot slip-table and integrated system base. The system shall also include a 5-foot by 5-foot, guided headed expander for mounting test articles in vertical operation.

The vibration test systems shall include the following components as a minimum:

a. An Electrodynamic Vibration Exciter.
b. An air-cooled Exciter Power Amplifier.
c. An Exciter Field coil Power Supply.
d. An Exciter Heat Exchanger/Cooling System.
e. A Vibration System Base/Slip Table System.
f. Interconnecting Cables, Hoses and Ducts
g. An Armature Position Control System.
h. Remote Armature Position Indicator(s).

3.1.1 System Operational Requirements.

3.1.1.1 Output.

a. **Sine Wave**: The vibration exciters shall generate a force output of at least 55,000 pounds force (lbf) peak continuous duty over the frequency range of at least 5 to 2,000 Hz in the full force (high field) mode.
b. **Random**: The vibration exciters shall generate a force output of at least 55,000 lbf root mean squared (rms) continuous duty, with a mass load of greater than 1000 lbs over the frequency range of 20 to 2,000 Hz (flat spectrum).
c. **Shock**: The vibration exciters shall generate a force output of at least 100,000 lbf peak for shock tests. The vibration exciter shall be capable as a minimum of performing the half-sine shock pulses included in Table 3.1.1.1-1.

Table 3.1.1.1-1. Shock Performance Half-Sine Pulses

Time Base (milliseconds)	Peak Acceleration (g)	Load on Armature (pounds)
15	80	600
15	50	2,000
11	125	25
11	100	850
6, 4	200	200
6, 4	100	900
6, 4	50	2,000

3.1.1.2 Frequency Range.

The large force electrodynamic vibration test system shall operate over the frequency range of 5 to 2000 Hz. The fundamental armature resonance with no mass attached shall be 1800 Hz or greater.

3.1.1.3 Displacement.

The large force electrodynamic vibration test system shall provide continuous displacement of at least 3.0 in_{pk-pk} for random vibration, shock, and sinusoidal vibration operation.

3.1.1.4 Armature Velocity.

The vibration exciter shall operate continuously at peak sinusoidal armature velocities of at least 85 inches per second (ips). The vibration exciter shall operate at peak shock velocity of up to at least 130 inches per second (ips).

3.1.1.5 Armature Acceleration.

The vibration exciter shall operate continuously, with a mass of at least 160 lbs attached to the armature, at peak sinusoidal and random vibration armature accelerations of at least 100 g.

3.1.1.6 Cross-Axis Motion.

The cross-axis motion (90 degrees to the thrust axis) of the armature to the exciter thrust center line, at 0.5 in_{pk-pk} displacement or 10 g (whichever is less) between 5 to 2000 Hz, shall not exceed 20% of the drive axis except for no more than two points.

3.1.1.7 Exciter Body Suspension Resonance.

With the exciter body supported and centered on the pneumatic suspension system, and with no mass load on the armature, the fundamental natural frequency of the exciter body suspension shall be no higher than 4 Hz in either the horizontal or vertical operational configuration.

3.1.1.8 Stray Magnetic Field.

The stray magnetic field shall be less than 20 gauss at a distance 6 inches above the armature-mounting surface.

3.2 Large Force Electrodynamic Vibration Exciter Requirements.

The large force electrodynamic vibration test system shall include an electrodynamic vibration exciter as necessary to meet the system operational requirements of paragraph 3.1.1.

3.2.1 Armature Head.

The vibration exciter armature-mounting surface shall have 45 replaceable stainless steel threaded inserts conforming to the 24-inch diameter head hole pattern as shown in Figure 3.2.1-1. The threaded inserts shall allow fixture attachment using ½-13 Unified National Course (UNC) bolts. The threaded inserts shall provide a minimum of 11/16 inches of thread depth. The total depth of the holes shall be at least 1.25 inches. The inserts shall be of stainless steel construction.

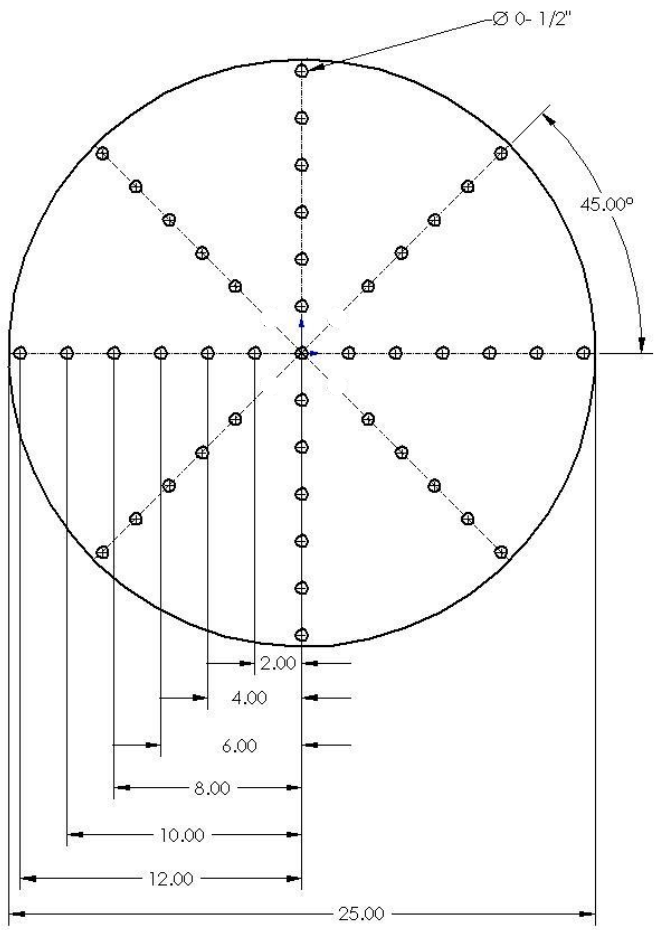

Figure 3.2.1-1. Armature Hole Pattern

3.2.2 Armature Load Capacity.

The armature shall support loads of at least 4000 lbm vertically without external supports.

3.2.3 Armature Cooling.

The large force electrodynamic vibration test system armature shall be primarily air cooled. Auxiliary cooling may be included to prevent excessive armature temperature during extreme operating conditions, however, no liquid shall flow through tubes, hoses or cavities within the moving element of the shaker.

3.2.4 Armature Positioning System (APS).

The large force electrodynamic vibration test system shall be provided with an automatic armature positioning system. The armature shall have a positioning system capable of re-centering the loaded armature to the mid-stroke position allowing full 3 $in_{pk\text{-}pk}$ displacement in both the vertical and horizontal configuration. The armature positioning system shall be adjustable to an off center position for shock testing.

3.2.4.1 APS General.

The APS shall include as a minimum, all valves, servomechanisms, sensors, interconnecting cables and hoses to automatically position the exciter armature with load attached. The external compressed air supply (see paragraph 4.3) input fittings shall be National Pipe Thread (NPT).

3.2.4.2 APS Load Capacity.

The APS shall automatically center the armature for mass loads of 0 to 4000 lbm with the exciter in the vertical configuration without the need for additional external supports.

3.2.4.3 APS Local Control.

The APS shall be provided with an armature position indication and control unit collocated with field coil power supply. Armature position indication and control accuracy shall be within ± 0.05 inches. The interconnecting cables and connectors for the local APS control and position indication unit shall be included.

3.2.4.4 APS Power Input.

The APS shall operate from 115 V_{rms} ± 5%, 60 Hz ± 5%, single phase, commercial electrical power.

3.2.4.5 APS Remote Control.

The APS shall include a remote indicator and control with ± 0.05 inches or less resolution, in a standard 19 inch equipment rack mount with up to 500 ft of cable.

3.2.5 Exciter Protective Devices.

The vibration exciter shall be equipped with the following protective devices as a minimum:

a. Armature Over-temperature Limits: The exciter shall be equipped with an armature over-temperature limit which prevents operation prior to the armature sustaining temperature induced damage.

b. Field and/or Stator Coil Over-temperature Limits: The exciter shall be equipped with an armature over-temperature limits which prevents operation prior to the field coils and/or stator coils sustaining temperature induced damage.

c. Mechanical Armature Stop(s): The exciter shall be equipped with elastomeric, or equivalent, armature stop(s), which reduce the severity of armature to body impacts.

d. Armature Over-travel Limits: The exciter shall be equipped with over-travel limits which stops exciter operation (electrically) prior to the armature contacting the mechanical stop(s).

e. Slip Table Hydraulic Power Supply Interlock: The exciter shall be equipped with an interlock to ensure that the slip table hydraulic power supplies are on when the exciter is used with a slip table. This interlock shall be equipped with a bypass when the slip table is not in use.

3.2.5.1 Exciter Cables.

The vibration exciter shall be provided with terminated armature excitation cables, minimum 60 feet (ft) in length, as required to meet the operational requirements of paragraph 3.1.1

3.2.6 Large Force Electrodynamic Vibration Test System Base.

The large force electrodynamic vibration test system shall include a unitized base, which integrates the exciter and slip table into a functional unit. The system base shall be configured to accommodate nominal test items on a slip table (5 foot x 5-foot).

3.2.6.1 Base Isolation.

The system shall include an automatic leveling base isolation system for nominal single shaker operation. The base shall be isolated from the test facility floor. The natural frequency (first single degree-of-freedom mode) of the electrodynamic vibration test system (base, exciter, slip tables, bearings) isolation shall be lower than 5 Hz in both the vertical and horizontal directions. The system base shall also include mounting provisions for securing the base to a facility floor reaction mass for performing coupled dual shaker vibration tests (future capability).

3.2.6.2 Base Mobility.

The base shall be equipped with air casters and lifting eyes (minimum of 4) such that the base and exciter can be lifted as an assembly using a crane and moved into position using the casters.

3.2.7 Slip Table System.

The large force electrodynamic vibration test systems shall include a slip table and bearing system as necessary to meet operational requirements of paragraph 3.1.1.

3.2.7.1 Size.

The primary slip table shall have a working surface with nominal dimensions of 60 inches by 60 inches.

3.2.7.2 Material.

The slip table shall be constructed from AZ31B magnesium alloy and shall be 3 inches thick. The working surface of the slip table shall be flat to 0.005 inch total indicated reading (TIR) and have a maximum roughness of 63 micro inches.

3.2.7.3 Hole Pattern.

The slip table working surface shall have a square grid pattern of ½-13 threaded inserts located on 4 inch by 4 inch centers with one hole of the grid centered on the working surface area and one side of the square grid parallel to the excitation axis and the other side perpendicular to the excitation axis (see Figure 3.2.7.4-1). The slip table shall include the armature hole pattern centered about the center hole of the 4-inch grid with ½-13 threaded inserts as shown in Figure 3.2.1-1. End to end tolerance from any one threaded insert center to any other threaded insert center shall not exceed ± 0.007 inch. The threaded inserts shall provide a minimum of 11/16 inches of thread depth. The total hole depth shall be 1.25 inches minimum. The inserts shall not protrude from the working surface. The inserts shall be of stainless steel construction.

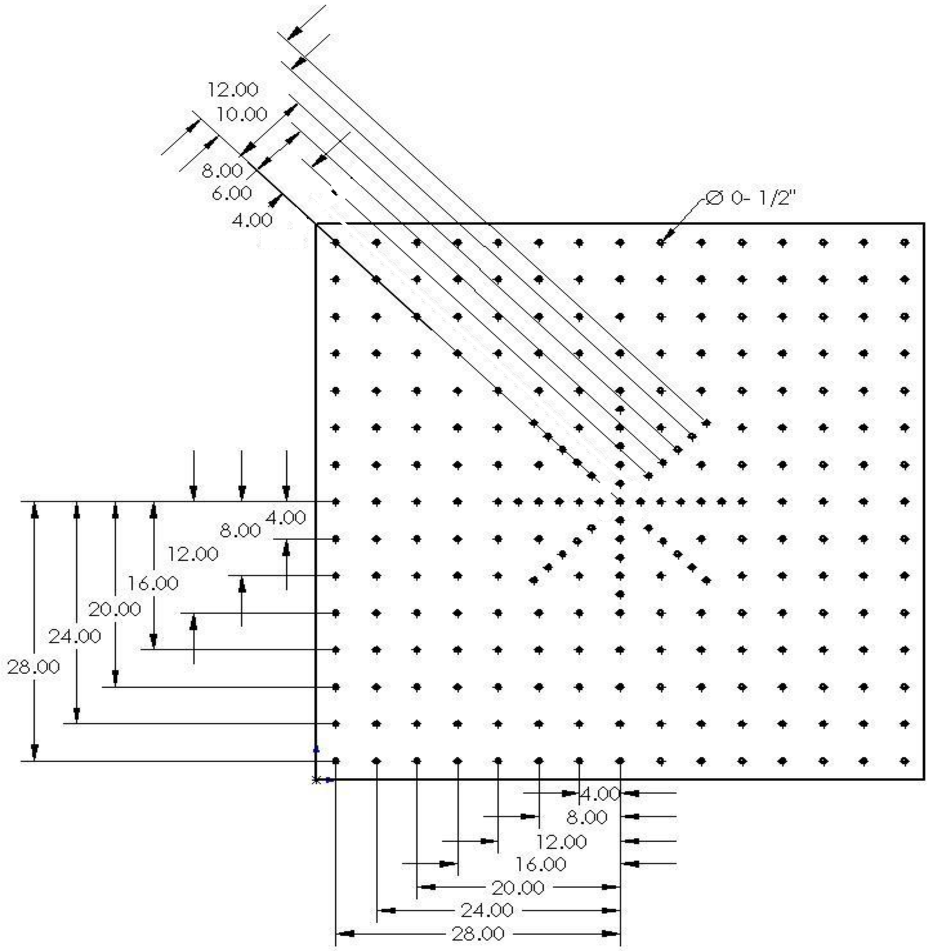

Figure 3.2.7.4-1. Slip Table Hole Pattern

3.2.7.4 <u>Thermal Barrier.</u>

The slip table shall be provided with a thermal barrier. The thermal barrier shall allow access to all the threaded inserts. The thermal barrier shall allow the slip table system to be used under temperature conditioned environments of -65° to 200° Fahrenheit for time periods exceeding 24 hours.

3.2.7.5 <u>Driver Bar.</u>

The slip table shall interface to the exciter by use of a driver bar. The driver bar shall mount to the armature by utilizing all 45 of the armature mounting holes. The system shall be such that the exciter with attached driver bar can be rotated from the horizontal to the vertical orientation without interference from the slip table. The driver bar shall interface with the slip table in such a way that the thrust forces generated by the exciter are transmitted to the slip table. The driver bar shall drive the slip table directly through the centerline (horizontal plane) of the exciter armature. The driver bar to slip table assembly process shall allow assembly and disassembly from the top surface.

3.2.7.6 Slip Table Bearing System.

The slip table bearing system shall be an integration of low-pressure oil-film granite, or equivalent and linear bearings which constrain the slip table motion to a single degree-of-freedom motion. The slip table bearing system shall meet the requirements noted in the following sections.

3.2.7.7 Displacement.

The bearing system shall allow slip table displacement which is greater than that of the exciter armature whether the exciter body is coupled or decoupled from the exciter base.

3.2.7.8 Granite.

The slip table bearing system granite shall be natural and not synthetic.

3.2.7.9 Moments.

The bearing system shall withstand low frequency (5 Hz or lower) dynamic moments of at least 50,000 ft-lbs applied to the slip table about yaw and pitch and at least 25,000 ft-lbs applied to the slip table in roll without sustaining damage or metal to metal contact.

3.2.7.10 Thermal Protection.

The bearing system shall be designed such that thermal expansion or contraction of the slip table, up to 0.05 inches across the table width, causes no binding or damage to the bearing system.

3.2.7.11 Hydraulic Power Supply.

The slip table bearing system shall include an integrated hydraulic power supply(s) as necessary to meet the requirements of this purchase description.

3.2.7.12 Re-circulation Oil Protection.

The slip table bearing system shall include barriers, or equivalent, that reduces contamination of particulate and water from entering the slip table re-circulating oil. The re-circulating oil system shall have a filtering system that removes water and particulate from the re-circulating oil.

3.2.7.13 Re-circulating Oil Conditioning System.

The slip table re-circulating oil shall have a conditioning system that maintains the re-circulating oil at the optimum performance temperature during testing at low temperature extremes.

3.2.7.14 Protective Devices.

The slip table bearing system shall be equipped with a hydraulic pressure sensor(s) which prevents operation when the hydraulic pressure is below safe operation pressure.

3.2.8 Exciter Body Rotation.

The system shall include provisions to rotate the exciter body by use of a gear mechanism about the trunnion axis from 0° (the thrust vertical axis) through 90° (the thrust horizontal axis). Provision for locking the exciter body in the 0° and 90° shall be provided.

3.2.9 Heat Exchanger/Cooling System.

The large force electrodynamic vibration test system shall include a water cooled heat exchanger system, which shall cool the exciter field coils and other fixed (non-moving) high current coils as required to meet the operational requirements of paragraph 3.1.1. The raw cooling water supply is discussed in paragraph 4.2. The system shall also include the air cooling system for the exciter armature.

3.2.9.1 Heat Exchanger/Cooling Hose(s).

If required, the heat exchanger system shall be provided with hose(s) a minimum of 60 ft in length, with connectors to interface to the exciter and heat exchanger system.

3.2.9.2 Heat Exchanger/Cooling air Duct(s).

The heat exchanger/cooling system shall be provided with air duct(s) a minimum of 25 ft in length, with connectors to interface the exciter to the heat exchanger/cooling system.

3.2.9.3 Heat Exchanger/Cooling Power Input.

The heat exchanger/Cooling system shall operate from one or more of the following commercial power sources available at WSMR test facilities:

a. 460 V_{rms} ± 10%, 60 Hz ± 5%, 3 phase (Primary).

b. 115 V_{rms} ± 10%, 60 Hz ± 5%, single phase (Control).

3.2.9.4 Heat Exchanger/Cooling Protective Devices.

The heat exchanger shall be equipped with the following protective devices as a minimum:

a. Outer Loop Water Pressure Limit(s). The heat exchanger/cooling system shall be equipped with an outer loop pressure limit which prevents operation of the electrodynamic vibration test system when the water pressure is not within the required pressure levels to operate the electrodynamic vibration test system without inducing damage to the system.

b. Inner Loop Water Pressure Limit(s): The heat exchanger/cooling system shall be equipped with an inner loop pressure limit which prevents operation of the electrodynamic vibration test system when the water pressure is not within the required pressure levels to operate the electrodynamic vibration test system without inducing damage to the system.

c. Inner Loop Flow Limit(s): The heat exchanger/cooling system shall be equipped with an inner loop flow limit which prevents operation of the electrodynamic vibration test system when the water flow is not within the required flow rate to operate the electrodynamic vibration test system without inducing damage to the system.

d. Air Flow/Pressure Limit(s): The air cooling system shall be equipped with an air flow/pressure limit which prevents operation of the electrodynamic vibration test system when the air flow/pressure is not within the required flow rate to operate the electrodynamic vibration test system without inducing damage to the system.

3.2.10 Field Coil Power Supply (FCPS).

The large force electrodynamic vibration test system shall include a field coil power supply which shall provide DC voltage and current as required by the exciter to meet the operational requirements of paragraph 3.1.1. The FCPS shall include at least two user selectable field strength current outputs (e.g., High and Low).

3.2.10.1 FCPS Cables.

The FCPS shall be supplied with terminated field coil excitation power cables of at least 60 ft in length.

3.2.10.2 FCPS Power Input.

The FCPS shall operate from one or more of the following commercial power sources available at the WSMR test facilities:

a. 460 V_{rms} ± 10%, 60 Hz ± 5%, 3 phase (Primary).

b. 115 V_{rms} ± 10%, 60 Hz ± 5%, single phase (Control).

3.2.10.3 FCPS Protection Device Field Voltage Limit(s).

The FCPS shall be equipped with a field voltage switch (es) which prevents operation of the electrodynamic vibration test system when the field voltage is not within the required voltage levels to operate the electrodynamic vibration test system without inducing damage to the system.

3.2.11 Power Amplifier (PA).

The large force electrodynamic vibration test system shall include a power amplifier, which shall provide variable frequency power to the exciter stator coils and front panel selectable two level DC voltage as required by the exciter to meet the operational requirements of paragraph3.1.1.

3.2.11.1 PA Rated Output.

The PA shall provide a rated output of at least 480 kilovolt amperes (KVA).

3.2.11.2 PA Harmonic Distortion.

The PA shall have a harmonic distortion of less than 0.5% from DC to 100 Hz and 2% from 100 to 2000 Hz.

3.2.11.3 PA Signal Input.

The PA shall receive an input signal of at least 2.5 V_{rms} or less.

3.2.11.4 PA Hum/Noise.

The PA shall not have a hum/noise level greater than 60 dB below full output with shorted input.

3.2.11.5 PA Cooling.

The PA shall be completely air-cooled. The total heat to air at full power shall not exceed 140,000 Btu/hr.

3.2.11.6 PA Over-voltage Limit Control.

The PA shall be equipped with an adjustable over-voltage limit control on the PA front panel.

3.2.11.6 PA Over-current Limit Control.

The PA shall be equipped with an adjustable over-current limit control on the PA front panel.

3.2.11.7 PA Cables.

The PA shall be supplied with terminated PA power cables of at least 60 ft in length. The PA shall be supplied with terminated PA to FCPS control cables of at least 30 ft in length.

3.2.11.8 PA Protective Devices.

The PA shall be equipped with the following protective devices as a minimum:

a. Peak Current Limit(s): The PA shall be equipped with a peak current limit which suspends PA operations prior to the PA or exciter sustaining current induced damage.

b. Peak rms Current Limit(s): The PA shall be equipped with a peak rms current limit which suspends PA operations prior to the PA or exciter sustaining rms current induced damage.

c. Peak Voltage Limit(s): The PA shall be equipped with a peak voltage limit which suspends PA operations prior to the PA or exciter sustaining voltage induced damage.

d. PA Over-temperature Limit(s): The PA shall be equipped with an over-temperature limit which suspends PA operations prior to the PA sustaining temperature induced damage.

e. A Door Open Limit(s): The PA shall be equipped with an open door limit which prevents the PA from being powered up if the PA door is open.

f. Slip Table Oil Pressure Limit(s): The PA shall be equipped with an interlock to ensure that the slip table oil pressure is at the operational required levels prior to PA achieving operational condition. This interlock shall be equipped with a bypass when the slip table is not in use.

g. PA Shock Protection: The PA shall have the capability to attain full line voltage from the off state over an interval of at least 500 milliseconds (ms) to prevent PA shock damage.

3.2.12 Control Panel.

The PA shall be equipped with a local control panel on the PA and a remote control panel. The remote control panel shall be rack mountable and include all the functionality of the local control panel. Operation from either control panel shall be selectable and the unused panel shall be automatically locked out.

3.2.12.1 Control Panel Switches and Indicators.

The following switches and indicator shall be included on the local and remote control panels as a minimum:

a. Remote/Local Switch
b. On/Off Switch
c. System Power Switch
d. Operate Switch
e. Vibration/Shock Switch
f. Gain Switch
g. Digital Input DC Voltage and Current Meters
h. Digital Output AC Voltage and Current Meters
i. Gain Level Indicator
j. Peak Current Indicator
k. Volt Limit Indicator
l. Shaker Temperature Indicator

m. Shaker Current Indicator

n. Shaker Field Indicator

o. Shaker Stroke Indicator

p. Shaker Heat Exchanger Indicator

3.2.12.2 Sine/Random Control.

The PA control system shall automatically sense the operation mode of sine or random, and automatically adjust the PA parameters for optimum performance. No manual switching shall be required to operate in either sine or random mode.

3.2.12.3 Remote Control Panel Cable.

The remote control panel shall be supplied with terminated PA cables of at least 500 ft in length.

3.2.13 Head Expander.

The large force electrodynamic vibration test system shall include a head expander with a unloaded natural frequency (first mode) of at least 580 Hz.

3.2.13.1 Head Expander Surface.

The head expander shall be a machined casting and shall have a table size of 60 inches by 60 inches. The head expander working surface shall have a square grid pattern of ½-13 threaded inserts located on 4 inch by 4 inch centers with one hole of the grid centered on the working surface area. End to end tolerance from any one threaded insert center to any other threaded insert center shall not exceed ± 0.007 inch. The threaded inserts shall provide a minimum of 11/16 inches of thread depth. The total hole depth shall be 1.25 inches minimum. The inserts shall not protrude from the working surface. The inserts shall be of stainless steel construction.

3.2.13.2 Head Expander Supports.

The head expander shall utilize at least four rigid linear bearings or equivalent to provide additional restraint and guidance. The head expander shall include airmounts (air bags or cylinders) located under the head expander. The airmounts shall integrate into the electrodynamic vibration test system's automatic centering system. The head expander supports shall provide support and centering for payloads of up to 12,000 lbs without external supports. The head expander with supports shall be removable to allow for exciter rotation in the horizontal axis without obstruction.

4. NOTES.

4.1 Intended Use.

The large force electrodynamic vibration test system will be used to perform shock and vibration tests of civilian and military materiel. The shock tests include classical pulse and synthesized shock tests. The vibration tests include wheeled and tracked vehicle transportation as well as missile flight environments. The large force electrodynamic vibration test system will be used for combined (temperature and vibration) environmental testing. For combined environment testing special purpose conditioning shrouds are fabricated which expose only the test item, fixture, and possibly the working surface of the vibration table directly to the extreme temperature conditions.

4.2 Raw Cooling Water.

The raw cooling water system at WSMR will provide at least 30 gallons per minute (gpm) of 40° to 70° Fahrenheit water.

4.3 External Compressed Air Supply.

The compressed air supply at WSMR provides up to 120 pounds per square inch (psi) of air pressure.